Information for Instrument Teams

The objective of the pages in this section is to provide comprehensive explanations of the procedures for spacecraft teams to participate in lunar calibration, including the items of information required and the file formats for communicating that information. Lunar calibration is applicable to any sensor system that has viewed the Moon, even ground-based instruments. To accommodate a wide variety of sensor configurations having different operational objectives, a set of Information Exchange Items with formalized Exchange File Formats has been developed.

The normal sequence of interaction between a Spacecraft Calibration Team (SCT) and the USGS Lunar Calibration Team (LCT) is:

1. Initial discussion between SCT and LCT about the suitability of lunar calibration for a specific instrument.
2. SCT provides the detailed spectral response for each instrument band.
3. LCT processes the spectral response data, and replies with the effective wavelengths for each band for white, solar, and lunar targets.
4. SCT becomes familiar with the data exchange items and file formats necessary to process their instrument Moon observations for lunar calibration (see Exchange File Formats).

For each lunar observation:

5. SCT processes their instrument lunar observation data and computes the necessary items of information, including the apparent (oversampled) lunar irradiance, calibrated to radiometric units.
6. SCT prepares the information exchange files for their lunar observations in the standard formats, and provides these to the LCT.
7. LCT computes the detailed geometry for each observation, queries the lunar irradiance model, and replies to the SCT with the geometry and irradiance comparison data.

These steps pertain exclusively to the use of disk-integrated lunar irradiance; procedures for comparison of spatially resolved lunar radiance will be available once a reliable radiance model is operational.

A major objective of the USGS lunar calibration program is to compare the radiance scales that are being used by the various spacecraft instruments. To facilitate this objective, SCTs are asked to provide their irradiance observations for comparison to the lunar irradiance model calculations. Lunar calibration results are communicated only to the SCT unless release is explicitly granted by the SCT.

Information Exchange Items

The two lists below define the interface between a Spacecraft Calibration Team (SCT) and the USGS Lunar Calibration Team (LCT) for model comparison of lunar irradiance observations. The interface is intentionally bilateral, i.e. the information will be available to both teams. There are standard Exchange File Formats for all items.

The SCT will provide to the LCT:

1. The system relative spectral response of each band. This is required only once unless the instrument is known to change.
2. The Universal Time (UTC) of the lunar observation. For scanning sensors, this is the time that the geometric center of the Moon is scanned, regardless of illumination. E.g. for push-broom systems, this is the time when the detector line array crosses the center of the Moon.
3. The location of the spacecraft at the above observation time, in (Earth-centered, inertial) J2000 Cartesian coordinates.

4. The oversampling of the Moon, or alternatively the apparent angular size of the Moon in the downtrack direction, in milliradians (Moon_Y_Size).
5. The apparent lunar irradiance measured in each band, without correction for distances or oversampling. Preferred units are microWatt m-2 nm-2. If the Moon is clipped, this is for the portion of the Moon observed. In order to track calibration histories, an identification of the radiometric calibration version used and the presumed pixel solid angle should be provided.
6. If the observed Moon is clipped, then the following two parameters are required for each focal plane. This assumes that the edge of coverage is a straight line across the lunar disk (a chord):
    1. The width of unobserved segment, as the angular distance from the center of the chord radially out to the lunar circumference expressed as a fraction of the lunar angular radius.
    2. The position angle of a line from the center of the Moon to the center of this chord, measured counterclockwise from equatorial celestial north.

The LCT provides to the SCT:

1. The spectral response data for each band, converted to an effective wavelength for a nominal lunar reflectance.
2. High precision geometry parameters pertaining to the locations of the Moon and Sun at the observation time, and all appropriate geometric correction factors.
3. Computation of the lunar irradiance model for the time and geometry of the spacecraft observation, interpolated the effective wavelengths of the spacecraft instrument bands. This includes correction for oversampling based upon the `Moon_Y_Size` parameter. Interpolations to spacecraft band wavelengths between the ROLO observational bands are done along a representative lunar reflectance curve. Panchromatic bands utilize a weighted sum of ROLO bands.
4. The discrepancy between the spacecraft measurement and the modeled lunar irradiance, expressed as a percentage: ((measured/model)-1.)*100%. This will include an identification of the lunar model version used.
5. If spacecraft image was clipped, an appropriate fractional correction to predict the irradiance from the entire Moon. (Prior to availability of a reliable lunar radiance model, this will be a simple geometric factor)

SCT Irradiance Processing

Spacecraft teams should produce an irradiance by doing a full radiance calibration of a lunar image using their usual or "best" calibration coefficients, presumably those used to produce their standard radiance data products. However, commonly a better zero-level radiance can be found from a lunar image (the surrounding space level) than from the standard data product processing. The irradiance is found by summing all the radiance pixels attributed to the Moon and multiplying by the nominal solid angle of a pixel (solid angle defined by sampling separation, not the MTF size of a pixel).

Note: this process is described in: H.H. Kieffer, P. Jarecke and J. Pearlman, "Initial Lunar Calibration Observations by the EO-1 Hyperion Imaging Spectrometer", Proc. SPIE **4480**, 247-258, (2002); however, the SCT should not do any of the oversampling or distance corrections described therein.

If the oversampling of the Moon in an observation is not known, then the SCT must determine the apparent length of the Moon in their image, in milliradians. This must be done as accurately as possible, as the value enters linearly into the irradiance calculation. This is the limb-to-limb extent in pixels, multiplied by the down-track angular line spacing for normal nadir imaging.

Exchange File Formats

Currently all information exchange between a Spacecraft Calibration Team (SCT) and the USGS Lunar Calibration Team (LCT) is done with ASCII text files. The amount of information to be exchanged is modest, and ASCII files are easily read by both humans and computers. Eventually, comparisons of the spatially resolved lunar radiance will likely require binary information exchange.

Spectral Response Files (required only once)

The SCT should provide the system-level relative spectral response for each band, with a spectral resolution on the order of 1 nm (for spectrometers, the nominal full-width at half-maximum will generally be adequate). Absolute scaling is not important; the response functions can be normalized. A useful format for the LCT is a two-column ASCII text file for each band, with the first column being wavelength in nm and the second column being transmission or response. For response, the LCT must know whether the detectors respond to photons or energy.

Note: Once a band order is established for an instrument, that order should be maintained for all future file exchanges. Model results can optionally be sorted into ascending wavelength order.

Lunar Observation Files

The exchange files are generated by the SCT and LCT in pairs that roughly parallel one another. There are different formats for single and multiple observations of the Moon, with the Multiple Observation Files more common (time series of lunar views are the most useful; multiple observations are strongly encouraged). Because these files are ASCII text for input to computer programs, adherence to the standard formats is essential.

Each file begins with a label section that contains "keyword=value" entries, terminated by a separate line containing `C_END`. This section is followed by a table section containing the observation parameters (SCT) or model results (LCT). The label section may contain subsections, marked by the special keyword `SECTION`. This is done for readability, to distinguish the observational data supplied by the SCT from the model results generated by the LCT.

A line in the label section has the following elements:

- A keyword, with no interior blanks. Valid keywords are listed and defined below. Keywords must appear exactly as in the list (case-sensitive).
- An equal sign = between the keyword and value, with any number of blanks on either side (or none).
- A value, which may be numeric or alpha-numeric. Embedded blanks are allowed, as are any number of surrounding blanks. Units may be indicated, enclosed between `<` and `>` -- this is for readability only, units for each item are prescribed.
- An optional description/comment, initiated by an exclamation mark `!`.
- The special keyword `BEGIN_FREE`, which starts a free-form area within the label section. This area typically is used to describe the table section, with column headers, formats, etc. This area may contain any number of text lines, and is terminated by the `C_END` line. For readability, free-form text lines that extend beyond 80 columns are discouraged.
- The `C_END` line, which is always the last line before the table section.

The table section begins immediately after the `C_END` line, therefore any explicit column headers must appear before this line. The items in the table section must be space (not tab) delimited. Alignment is encouraged for human readability, but is not strictly required.

The contents of the label and table sections differ for single-observation and multi-observation files. For single observation files, the label section contains the observation geometry information, while the table section lists the irradiance information for each instrument band. For multiple observations, two sets of files are used, one (SCT/LCT pair) for geometry, one for irradiance. The rows of the table sections correspond to individual lunar observations, with the instrument bands arranged in columns. To accommodate all bands in one row, the table sections of these files can exceed an 80-character width. Further explanations of the table section contents have been appended in the examples below:

Example SCT Single Observation File

```
Instrument = EO-1 ALI
User = Jeff Mendenhall
Source_Date =                      ! Run Date/Time of primary input file
Image_Time = 2001-11-01T21:05:43.
Spacecraft_X = 5888.7  ! <km>
Spacecraft_Y = 1731.5  ! <km>
Spacecraft_Z = -3543.1 ! <km>
Moon_Y_size =   75.80              ! <mrad> Moon apparent diameter
Missing_Fraction =   0.0000              ! Areal fraction of Moon not observed
BEGIN_FREE      ! Begins a free-form section describing the table section
     This is a ROLO exchange file for:   SCT Single-Observation
Col_0=index   col_1=band   col_2=nom. wavelength <nm>
Col_3=Instrument Irradiance <microW m^-2 nm^-1>
C_END
  1      1p    442.   26.36
  2      1     485.   30.67
  3      2     567.   32.75
  4      3     660.   30.63
  5      4     790.   26.03
  6      4p    865.   21.71
  7      5p   1245.   13.63
  8      5    1640.    7.39
  9      7    2225.    3.01
  10   10Pan   592.   28.47
```

The label section contains the geometry parameters for the observation. For keyword definitions, see <Exchange File Formats>.

The contents of the table section are:

* column 1: A unity-based index of instrument bands

* column 2: The instrument-specific band identifier, numeric or alpha-numeric

* column 3: The nominal band center wavelength, expressed in nm

* column 4: The apparent lunar irradiance, in units of microWatts meter^-2 nanometer^-1

Additional columns (such as uncertainty) can easily be included in the tables.

Example LCT Single Observation File

```
SECTION = Observation info             ! ---------------------- Begin a section
Instrument = EO-1 ALI                    ! Instrument makeing the observation
User = Jeff Mendenhall               ! Person submitting the calibration request
Source_Date =                            ! Run Date/Time of primary input file
Image_Time = 2001-11-01T21:05:43.        ! UTC at the middle of the observation
S_file_Name = 1            ! Name or lable of file received from Spacecraft team
Spacecraft_X =   5888.700    ! <km> Spacecraft X position at image-time in J2000
Spacecraft_Y =   1731.500    ! <km> Spacecraft Y position at image-time in J2000
```

```
Spacecraft_Z =  -3543.100    ! <km> Spacecraft Z position at image-time in J2000
Moon_Y_size =   75.8000               ! <mrad> Moon apparent diameter along slew
Missing_Fraction =   0.0000               ! Areal fraction of Moon not observed
Clip_Angle =    0.000   ! <degree> Position Angle of missing section, ccw from N
SECTION = ROLO_Calculations             ! ----------------------- Begin a section
Process = iradcal                      ! Name of process that generated this file
Version = 2005jul23                       ! Processing version
Run_Time = 2006Feb14 12:58:00             ! Local Date/Time of these calculations
Lunar_model = 311g = [coeff=r311g adjust=r311g05 ] ! Identification of the Lunar
irradiance model used
Barycentric_Time =   2452215.3797127609 ! <day> Dynamical barycentric Julian date
Sun_Moon_lon =  -11.935            ! <degree> Selenographic longitude of the Sun
Sun_Moon_lat =    1.224             ! <degree> Selenographic latitude of the Sun
SC_Moon_lon =   -3.748          ! <degree> Selenographic longitude of spacecraft
SC_Moon_lat =    3.880           ! <degree> Selenographic latitude of spacecraft
SC_Distance = 386394.7         ! <km> Distance of spacecraft from center of Moon
Sun_Moon_Distance = 0.9948765             ! <AU> Heliocentric range of the Moon
Distance_Factor =  1.000078 ! Factor to correct irradiance to standard distances
Phase_angle =    8.599                    ! <degree> Signed phase angle
Moon_Diam_Angle =   8.9929                ! <mrad> Diameter of the Moon from SC
Axis_Angle =  -14.916        ! <degree> Position Angle of lunar axis, ccw from N
Oversample_Factor =    8.429              ! Image oversample factor
Flux_Factor =  0.118640     ! Factor for Units, Oversample and missing fraction
NOTE =
NOTE = Col_0=index   col_1=band   col_2=nom. wavelength <nm>
NOTE = Col_3=Instrument Irradiance <microW m^-2 nm^-1>  Col_4=effective wavelength
NOTE = Col_5=model Irradiance   col_6=% disagreement   col_7=Instrument: scaled
C_END
  0   1p  442.00 26.3600    442.25  2.8969   7.96  3.1273
  1    1  485.00 30.6700    485.70  3.3652   8.13  3.6387
  2    2  567.00 32.7500    568.29  3.5884   8.28  3.8854
  3  Pan  592.00 28.4700    596.45  3.5199  -4.04  3.3777
  4    3  660.00 30.6300    660.17  3.4093   6.59  3.6339
  5    4  790.00 26.0300    789.97  2.8405   8.72  3.0882
  6   4p  865.00 21.7100    865.61  2.4398   5.57  2.5757
  7   5p 1245.00 13.6300   1244.20  1.5005   7.77  1.6171
  8    5 1640.00  7.3900   1637.83  0.9123  -3.90  0.8767
  9    7 2225.00  3.0100   2218.78  0.3390   5.35  0.3571
```

The label section is supplemented with ephemeris and geometric correction parameters computed by the LCT. For keyword definitions, see <Exchange File Formats>.

The contents of the table section are:

* column 1: A zero-based index of instrument bands

* column 2: The instrument-specific band identifier, in wavelength order

* column 3: The nominal band center wavelength in nanometers

* column 4: The apparent instrument lunar irradiance, in microWatts meter^-2 nanometer^-1

* column 5: The effective wavelength of the band for a lunar spectrum, in nanometers

* column 6: The lunar model irradiance for the observation conditions, in microWatts meter^-2 nanometer^-1

* column 7: The percent disagreement between the spacecraft and lunar model, as ((spacecraft/model)-1.)*100%

* column 8: The spacecraft irradiance for the complete Moon, after applying the Flux_Factor

Example SCT Geometry Multiple Observation File

```
SECTION = Observation info             ! ----------------------- Begin a section
Instrument = EO-1 ALI                  ! Instrument makeing the observation
User = Jeff Mendenhall                 ! Person submitting the calibration request
Source_Date =                          ! Run Date/Time of primary input file
Process = MIT/LL IDL                   ! Name of process that generated this file
Version = 2002sept10                   ! Processing version
Run_Time = 2003 Dec 04                 ! Local Date/Time of these calculations
BEGIN_FREE      ! Begins a free-form section describing the table section
     This is a ROLO exchange for:   SCT MOS geometry
Col_0=Obs_index   col_1=Image_time   col_2,3,4=Spacecraft_X,Y,Z
Col_6=Moon_Y_Size  [ Col_7=Miss_Frac  Col_8=Clip_angle ]
Format = (i3,1x,a21,3f9.1,f10.3,f7.4,f7.1)
C_END  End of label section
  1  2001-02-07T19:45:11.  -2379.9   4967.5  -4460.5    80.67 0.0000    0.0
  2  2001-03-10T04:10:11.  -4183.0   2697.5  -5046.4    80.14 0.0000    0.0
  3  2001-04-07T17:44:44.  -4776.8    339.5  -5225.6    81.57 0.0000    0.0
  4  2001-05-08T02:06:43.  -2508.3  -1717.5  -6403.8    80.18 0.0000    0.0
  5  2001-06-05T10:42:11.   -266.7  -1656.5  -6887.8    76.99 0.0000    0.0
  6  2001-07-06T06:43:44.    185.4  -2893.7  -6469.0    70.89 0.0000    0.0
  7  2001-08-04T21:02:44.   1580.3  -2500.0  -6442.0    72.28 0.0000    0.0
  8  2001-09-02T07:20:44.   2687.4  -1620.7  -6356.0    70.64 0.0000    0.0
  9  2001-10-03T01:46:44.   5186.7   -950.7  -4736.7    72.81 0.0000    0.0
 10  2001-11-01T21:05:43.   5888.7   1731.5  -3543.1    75.80 0.0000    0.0
```

The label section contains information on the processing used to create this file. For keyword definitions, see <Exchange File Formats>.

The table section contains a row for each lunar observation. The columns are the observation geometry parameters, exactly analogous to the keywords defined for a SCT Single Observation File.

* column 1: A unity-based index of instrument lunar observations

* column 2: Image_Time

* column 3: Spacecraft_X

* column 4: Spacecraft_Y

* column 5: Spacecraft_Z

* column 6: Moon_Y_size

* column 7: Missing_Fraction

* column 8: Clip_Angle

Example SCT Irradiance Multiple Observation File

```
SECTION = Observation info     ! ----------------------- Begin a section
Instrument = EO-1 ALI          ! Instrument makeing the observation
User = Jeff Mendenhall                ! Person submitting the calibration request
Process = MIT/LL IDL           ! Name of process that generated this file
Version = 2002sept10           ! Processing version
Run_Time = 2003 Dec 04         ! Local Date/Time of these calculations
BEGIN_FREE ! Begins a free-form section describing the table section
       This is a ROLO exchange for: SCT MOS Irradiance
```

```
                See matching Geometry file for comments
Col_0 = Obs_index Col_1+ = Irradiance in bands
Units are: microWatts / m^2 / nm
Format = (i3,12f9.4)
-1 1p 1 2 3 4 4p 5p 5 7 Pan
-2 442. 485. 567. 660. 790. 865. 1245. 1640. 2225. 592.
C_END End of label section
1       33.06   38.56   41.14   39.30   33.53   28.23   17.50   9.50    3.87    35.42
2       30.75   35.63   37.83   35.55   30.19   25.16   15.68   8.46    3.43    33.21
3       31.04   36.13   38.51   36.32   30.94   25.88   16.18   8.72    3.55    33.41
4       29.43   34.22   36.41   34.18   29.04   24.28   15.12   8.16    3.30    31.61
5       26.46   30.80   32.88   30.73   26.17   21.87   13.72   7.42    3.01    28.52
6       24.49   28.39   30.09   28.05   23.72   19.75   12.29   6.62    2.67    26.48
7       23.63   27.41   29.19   27.21   23.06   19.20   12.04   6.50    2.63    25.53
8       24.34   28.28   30.09   28.10   23.83   19.87   12.42   6.69    2.71    26.18
9       25.27   29.31   31.16   29.05   24.60   20.46   12.75   6.89    2.79    27.29
10      26.36   30.67   32.75   30.63   26.03   21.71   13.63   7.39    3.01    28.47
```

The label section contains information on the processing used to create this file. For keyword definitions, see <Exchange File Formats>.

The table section contains a row for each lunar observation, which must be aligned with the SCT Geometry Multiple Observation File. Instrument bands are arranged in columns. The table section can exceed 80-character width.

* column 1: A unity-based index of instrument lunar observations

* columns 2-n: For each instrument band, the apparent lunar irradiance in microWatts meter^-2 nanometer^-1

Example LCT Geometry Multiple Observation File

```
SECTION = Observation info             ! ---------------------- Begin a section
Instrument = EO-1 ALI                    ! Instrument makeing the observation
User = Jeff Mendenhall               ! Person submitting the calibration request
Source_Date = 2003 Dec 04                ! Run Date/Time of primary input file
Process = iradcal & multimoon         ! Name of process that generated this file
Version = 2005jul23 & 2005jul24          ! Processing version
Run_Time = 2006Feb14 13:57:12            ! Local Date/Time of these calculations
BEGIN_FREE      ! Begins a free-form section describing the table section
     This is a ROLO exchange for:   LCT MOF geometry
GUIDE to columns below:
Col          Key   units  Description
  0          Row       -  Observation Count
  1  TDB-2451545     day  Dynamical barycentric Days -2451545.
  2       SunLon  degree  Selenographic longitude of the Sun
  3       SunLat  degree  Selenographic latitude of the Sun
  4       SC_Lon  degree  Selenographic longitude of spacecraft
  5       SC_Lat  degree  Selenographic latitude of spacecraft
  6     SC_Dist.      km  Distance of spacecraft from center of Moon
  7   Sun_M_Dist      AU  Heliocentric range of the Moon
  8      DistFac       -  Factor to correct irradiance to standard distances
  9     PhaseAng  degree  Signed phase angle
 10    Moon_mrad    mrad  Angular Diameter of the Moon from SC
 11     Axis_Ang  degree  Position Angle of lunar axis, ccw from N
Format =
(I3,1x,f13.6,1x,f8.2,1x,f5.2,1x,f6.2,1x,f6.2,1x,f8.1,1x,F9.7,1x,f9.6,1x,F8.3,1x,f8.4,1x,f
8.3)
Row   TDB-2451545  SunLon SunLat SC_Lon SC_Lat SC_Dist. Sun_M_Dist  DistFac PhaseAng
Moon_mrad Axis_Ang
C_END  End of label section
```

```
  1    403.323792     6.40 -0.89  -0.44  -4.11 353512.4 0.9887706  0.826863   -7.561
9.8294   17.931
  2    433.674469    -2.95 -1.42   3.27  -7.25 358957.7 0.9955547  0.864271    8.513
9.6802   23.970
  3    462.240143     8.95 -1.52   3.48  -7.37 363747.8 1.0036108  0.901913   -7.995
9.5528   22.785
  4    492.588745    -1.29 -1.19   5.08  -5.42 377681.8 1.0117936  0.988255    7.634
9.2003   12.921
  5    520.946716    12.31 -0.57   4.80  -4.16 384838.9 1.0171890  1.037037   -8.318
9.0292    7.981
  6    551.781128    -4.50  0.26   3.00   1.17 396448.7 1.0192988  1.105122    7.555
8.7648  -10.688
  7    581.377625    -6.21  1.00   0.96   4.03 401291.3 1.0170912  1.127385    7.783
8.6590  -19.674
  8    609.806824     6.53  1.47   0.30   5.02 401747.1 1.0115631  1.117698   -7.160
8.6492  -22.275
  9    640.574890    -8.82  1.57  -2.63   5.84 395920.5 1.0032324  1.067708    7.505
8.7765  -22.098
 10    670.379700   -11.94  1.22  -3.75   3.88 386394.7 0.9948765  1.000078    8.599
8.9929  -14.916
```

The label section propagates the processing information used to create the SCT Multiple Observation Files, and adds explanations of the columns in the table section, including FORTRAN-style format statements and aligned column headers.

The table section contains a row for each lunar observation, row-aligned with the SCT Multiple Observation Files. The columns give the ephemeris and geometric correction parameters computed by the LCT, analogous to the keywords defined for a LCT Single Observation model results file. For keyword definitions, see <Exchange File Formats>.

* column 1: A unity-based index of instrument lunar observations

* column 2: Barycentric_Time minus 2451545.0

* column 3: Sun_Moon_lon

* column 4: Sun_Moon_lat

* column 5: SC_Moon_lon

* column 6: SC_Moon_lat

* column 7: SC_Distance

* column 8: Sun_Moon_Distance

* column 9: Distance_Factor

* column 10: Phase_angle

* column 11: Moon_Diam_Angle

* column 12: Axis_Angle

Example LCT Irradiance Multiple Observation File

```
SECTION = Observation info             ! ---------------------- Begin a section
Instrument = EO-1 ALI                     ! Instrument makeing the observation
User = Jeff Mendenhall                ! Person submitting the calibration request
Process = iradcal & multimoon          ! Name of process that generated this file
Version = 2005jul23 & 2005jul24           ! Processing version
```

```
Run_Time = 2006Feb14 13:57:12            ! Local Date/Time of these calculations
Lunar_model = 311g = [coeff=r311g adjust=r311g05 ]
 !! Corrections:
BEGIN_FREE      ! Begins a free-form section describing the table section
     This is a ROLO exchange for:   LCT MOF Irradiance
         See matching  Geometry  file for comments
GUIDE to columns below:
Headers: Row-1=band
         Row-2=Nominal wavelength
         Row-3=Effective wavelength for the Moon
Table  : Col_0=count   Col_1=oversample factor.  Remaining columns are
         % disagreement, with a row for each observation
         (Spacecraft_Irradiance/ROLO_Irradiance -1.) in percent.
Format = (i3,f8.4,12f8.2)
 -1             1p       1       2     Pan       3       4      4p      5p       5
7
 -2           442.    485.    567.    592.    660.    790.    865.   1245.   1640.
2225.
 -3         442.25  485.70  568.29  596.45  660.17  789.97  865.61 1244.20 1637.83
2218.78
C_END  End of label section
  1  8.2070    7.97    8.47    8.63   -4.64    9.29   12.00    9.98   11.12   -0.56
9.30
  2  8.2787    7.91    7.62    7.15   -4.12    5.94    7.96    4.82    6.25   -5.68
2.88
  3  8.5389    7.26    7.48    7.46   -4.96    6.65    9.05    6.39    8.32   -3.83
5.42
  4  8.7149    8.62    8.80    8.68   -3.79    7.47    9.71    6.91    8.48   -3.52
5.32
  5  8.5267    6.65    6.84    6.93   -5.47    5.10    7.35    4.65    6.85   -4.84
3.78
  6  8.0880    9.89    9.74    9.22   -1.97    7.29    9.04    5.79    7.27   -4.77
3.74
  7  8.3473    6.35    6.26    6.23   -5.25    4.32    6.22    3.04    5.24   -6.40
2.20
  8  8.1672    7.45    7.57    7.50   -4.61    5.79    7.83    4.88    6.92   -5.00
4.03
  9  8.2960    7.78    7.71    7.55   -3.93    5.68    7.58    4.23    5.85   -5.73
3.16
 10  8.4289    7.96    8.13    8.28   -4.04    6.59    8.72    5.57    7.77   -3.90
5.35
```

The label section propagates the processing information used to create the SCT Multiple Observation Files, and adds explanations of the columns in the table section, including FORTRAN-style format statements and aligned column headers.

The table section contains a row for each lunar observation, row-aligned with the SCT Multiple Observation Files. The table gives the lunar model results as comparisons, with the instrument bands arranged in columns. The table section can exceed 80-character width.

* column 1: A unity-based index of instrument lunar observations

* column 2: The Oversample_Factor (see <Exchange File Formats>)

* columns 3-n: For each instrument band, the percent disagreement between the spacecraft and lunar model, as ((spacecraft/model)-1.)*100%

Label Section Keywords

The keywords appearing in an exchange file label section are specific to the file type. Keyword definitions for each file type are listed below. All keywords must appear in the label section of SCT files, in the order listed (except the optional keyword NOTE).

SCT Single Observation File Keywords

`Instrument` = A unique identification of the instrument, possibly including separate optical components, e.g. ASTER SWIR. Internal blanks are allowed.

`User` = The name of the (one) person representing the SCT. Internal blanks are allowed.

`Image_Time` = Coordinated Universal Time (UTC) of the observation. For a push-broom system, this should be the time when the scan line crossed the geometric center of the Moon. The format is specific, and consistent with ISO-8601 (See http://www.w3.org/TR/NOTE-datetime). It must follow exactly (as in the single observation example linked above, 2001-11-01T21:05:43.):

> four decimal characters of year
> a dash (`-`)
> two decimal characters of month
> a dash (`-`)
> two decimal characters of day within month
> a "T" (`T`)
> two decimal characters of hour
> a colon (`:`)
> two decimal characters of minute
> a colon (`:`)
> two decimal characters of integral second
> optionally followed by a decimal point and decimal fraction of a second.

`Spacecraft_X` = The X coordinate of the spacecraft position at `Image_Time` in the J2000 coordinate system, expressed in kilometers. This is the non-rotating coordinate system normally used for orbital dynamics calculations.

`Spacecraft_Y` = The corresponding Y coordinate.

`Spacecraft_Z` = The corresponding Z coordinate.

`Moon_Y_size` = The apparent diameter of the Moon in the direction of elongation (or compression) of the image due to scanning, expressed in milliradians. This is measured to the geometric limbs, one possibly unilluminated. If the oversampling of the observation is known accurately, then this keyword can contain the oversampling factor (the SCT must inform the LCT if the oversampling factor is being used). For a framing imaging system that completely captures the Moon with short exposure time, this value is not needed (keyword is set to zero).

The following two keywords are relevant only if the Moon was not completely captured in the image, hence in the irradiance sum.

`Missing_Fraction` = The areal fraction of the geometric Moon not represented in the irradiance sum.

`Clip_Angle` = The azimuthal angle measured counterclockwise about the geometric center of the Moon from Celestial North to the middle of the missing section, expressed in degrees.

`NOTE` = A free-form line containing any additional text.

LCT Single Observation File Keywords

The label section for a LCT Single Observation File contains two subsections, marked by `SECTION =` lines. The first repeats the SCT label information, as a check. The second contains the computed geometric parameters for the observation, in the following keywords.

`Process` = The name of the software system that ran the model comparison.

`Version` = The version date of the Process software that was used.

`Run_Time` = The local date and time of the model run, as YearMonthDay hour:minute:second

`Lunar_model` = Identification of the lunar model version used. This includes identification of the model coefficients files used.

`Barycentric_Time` = `Image_Time` converted to barycentric dynamical time, expressed as a double-precision Julian date. This is the continuous, uniform time system used for planetary ephemeris calculations, and differs somewhat from UTC.

`Sun_Moon_lon` = The Selenographic longitude of the sub-solar point on the Moon, in degrees.

`Sun_Moon_lat` = The Selenographic latitude of the sub-solar point on the Moon, in degrees.

`SC_Moon_lon` = The Selenographic longitude of the sub-spacecraft point on the Moon, in degrees.

`SC_Moon_lat` = The Selenographic latitude of the sub-spacecraft point on the Moon, in degrees.

`SC_Distance` = The distance of the spacecraft from the center of the Moon at `Image_Time`, in kilometers.

`Sun_Moon_Distance` = The distance from the center of the Sun to the center of the Moon at Image_Time, in Astronomical Units (AU).

`Distance_Factor` = The multiplying factor to convert measured irradiance to that expected with the same geometric angles but with the spacecraft and Sun at standard distances from the Moon (384,400 km and 1 AU, respectively).

`Phase_angle` = The Sun-Moon-Spacecraft angle, in degrees, negative before Full Moon.

`Moon_Diam_Angle` = The angular diameter of the Moon (assumed circular) viewed from the spacecraft at Image_Time, expressed in milliradians.

`Axis_Angle` = The apparent orientation of the Lunar North polar spin axis, measured counterclockwise from Celestial North, in degrees.

`Oversample_Factor` = The image oversample factor, i.e. the factor by which the simple irradiance sum of a spacecraft image over-represents the true irradiance.

`Flux_Factor` = A composite multiplication factor applied to the spacecraft apparent irradiance to account for oversampling, any missing fraction of the Moon, and any radiometric units conversion.

SCT Multiple Observation File Keywords

SCT geometry and irradiance Multiple Observation Files are typically generated by some sort of automated process from primary data files native to the SCT. The keywords for these files are intended to track their origin, and are used only to propagate this information to the LCT files. The keywords for SCT Geometry and Irradiance Multiple Observation Files are identical.

`Instrument` = A unique identification of the instrument, possibly including separate optical components, e.g. ASTER SWIR. Internal blanks are allowed.

`User` = The name of the (one) person representing the SCT. Internal blanks are allowed.

`Source_Date` = The date and time of the primary SCT observational data file.

`Process` = the name of the software system that created this input file.

`Version` = The version date of the Process software that was used.

`Run_Time` = The data and time when this input file was created by Process. Internal blanks are allowed.

LCT Multiple Observation File Keywords

The Instrument and User keywords from the SCT Multiple Observation Files are propagated to the LCT geometry and model results Multiple Observation Files. The keywords Process and Version are modified to values for the software system that ran the model comparison. `Run_Time` is updated to the local date and time of the model run. One new keyword is added to the LCT model results file:

`Lunar_model` = Identification of the lunar model version used. This includes identification of the model coefficients files used.

The `BEGIN_FREE` sections generated for LCT Multiple Observation Files contain extensive explanations of the columns, including FORTRAN-style format statements and column-aligned headers.